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COMBINING BLACK-BOX TECHNIQUES WITH PHYSICS-BASED SURROGATES IN QUASI-NEWTON METHODS

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Many problems can be reduced to finding the root of a black-box system. For example, partitioned fluid-structure interaction (FSI) problems with strong coupling can often be solved efficiently with a quasi-Newton method such as IQN-ILS [1]. This algorithm creates a low order approximate inverse of the Jacobian of the black-box, using old inputs and outputs from previous coupling iterations and timesteps.

For some root-finding problems, additional information or an analytical expression may be available for the black-box, so that it is possible to come up with a surrogate model that covers part of the physics involved. *The Quasi-Newton with Least-Squares and Surrogate* (QN-LeSS) method is presented in this work: it combines a physics-based surrogate model of the black-box system with the aforementioned IQN-ILS method, in order to reduce the required number of quasi-Newton iterations. This surrogate may have the form of a matrix, a more general linear operator or even a non-linear function, as long as it evaluates significantly faster than the original black-box system. For the partitioned FSI problem, it can be shown that the IQN-ILS method is actually a special case of QN-LeSS, with Gauss-Seidel iterations as surrogate model.

QN-LeSS is demonstrated by solving the steady free surface problem. This root-finding problem requires an accurate surrogate model, that is based on a perturbation analysis of inviscid free surface flow [2]. The problem is complicated by the fact that the steady free surface problem is not well defined: boundary conditions must be added to the system to find a unique solution. As illustration, the wave pattern caused by an obstacle is calculated.

REFERENCES

[1] Degroote, J., Bathe, K.J., and Vierendeels, J. Performance of a new partitioned procedure versus a monolithic procedure in fluid—structure interaction. *Comput. Struct.*, Vol. **87.11–12**, pp. 793-801, (2009).

[2] Demeester, T., Degroote, J., and Vierendeels, J. Stability analysis of a partitioned iterative method for steady free surface flow. *J. Comput. Phys.*, Vol. **354**, pp. 387–392, (2018).